ERDC Project No. 2511

Intensive Field Trial of Ethanol/Petrol Blend in Vehicles

Executive Summary

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1. ACCOUNTABILITY

1.1 Project Need

Ethanol/petroleum fuel blends directly address vehicle exhaust emissions and transport fuel security of supply issues. The renewable ethanol content of these fuels can result in a net reduction in the emission of carbon dioxide ("greenhouse gas") as well as reduce currently regulated vehicle exhaust emissions of carbon monoxide (CO) and hydrocarbons (HC). Use of ethanol/petroleum fuel blends initially in the existing vehicle fleet is essential to develop the technology and infrastructure necessary to support widescale production and use of ethanol fuel.

In the United States, Brazil and Sweden there is already widespread use of ethanol fuel and/or ethanol/petroleum fuel blends, while in many other countries such blends are being introduced. In Australia, Bowen Petroleum Services, Burmah Fuels and Marina Petroleum have been marketing 10% v/v ethanol/petrol blends (ULP and Super) within their respective market areas since 1992. Currently, approximately 16 million litres of fuel ethanol is sold in Australia each year.

This project addresses the need to:

- identify the effects resulting from introduction of ethanol fuel into the transport sector; and,
- provide Federal and State Governments with reliable information to assist in the development of effective strategies for achieving reductions in greenhouse gas and noxious emissions from the transport sector.

1.2 Project Objectives

The project objectives were to:

- establish the contribution of 10% v/v ethanol/petrol blend to reducing greenhouse gas and noxious emissions;
- compare fuel consumption of 10% v/v ethanol/petrol blend with that of neat petrol;
- compare vehicle drivability on 10% v/v ethanol/petrol blend with that on neat petrol under various climatic conditions;
- examine fuel system component materials for compatibility with 10% v/v ethanol/petrol blend;
- compare engine wear on 10% v/v ethanol/petrol blend with that on neat petrol;
- examine water tolerance issues arising from storage, distribution and use of 10% v/v ethanol/petrol blend.

1.3 Findings and Conclusions

10% v/v ethanol/petrol blend offers significant benefits in terms of reductions in exhaust and greenhouse gas emissions with no apparent detrimental effect on other aspects of engine or vehicle performance.

When measured according to ADR37 protocol (SHED test) there is a significant increase in evaporative emissions with 10% v/v ethanol/petrol blend compared to neat petrol. However, there is no increase in ozone formation potential with 10% v/v ethanol/petrol blend due to the lower ozone formation potential of the exhaust emissions from 10%v/v ethanol/petrol blend. In the United States the ADR37 SHED test method has been replaced by the “Multiday Diurnal” SHED test method which is considered by U.S. EPA to more accurately model "real world" conditions. United States reports suggest that, when tested using the Multiday Diurnal SHED test method, the mass of evaporative emissions from 10% v/v ethanol/petrol blend is not significantly different to that from neat petrol.

Further work needs to be undertaken to determine the "real world" evaporative emission from 10% v/v ethanol/petrol blend.

It is estimated that the 1999 passenger vehicle fleet comprises approximately 25% pre-1986 vehicles using leaded petrol (LP) and 75% 1986-on vehicles using unleaded petrol (ULP). The results of this project for the 1999 fleet composition show that, when compared to use of neat petrol, use of 10% v/v ethanol/petrol blend has the following effects:

- Regulated exhaust emissions:
  - ~ CO decreases by approximately 32%;
  - ~ THC decreases by approximately 12%; and
  - ~ NOx increases by approximately 1%.

  Note: The large decrease in CO emission and the resultant decrease in health risk is the main reason for the mandating of use of oxygenates in CO non-attainment areas in the United States.

- Non-regulated exhaust emissions:

  “Toxics”
  - ~ 1-3 butadiene decreases by approximately 19%;
  - ~ benzene decreases by approximately 27%;
  - ~ toluene decreases by approximately 30%;
  - ~ xylenes decrease by approximately 27%;

Aldehydes

~ formaldehyde increases by approximately 25%;

~ acetaldehyde increases by approximately 180%; and,

~ acrolein increases by about 5%.

Note:

1. The value for acrolein is indicative only and must be treated with extreme caution.

2. The large increase in acetaldehyde emission is from a low base level and does not result in an overall increase in ozone formation potential or health risk assessments.

Carbon Dioxide

~ exhaust CO_2 increases by 1%; however,

~ net CO_2 emission decreases by up to 7% on full carbon cycle basis.

♦ Evaporative emissions (SHED test method - ADR37 protocol):

~ "diurnal" increases by approximately 10% ;

~ "hot soak" increases by approximately 40%;

Note: It is reported that there is little or no increase in evaporative emissions with the Multiday Diurnal SHED test method in force in the United States since January 1996.

♦ Ozone formation potential:

~ of exhaust emissions decreases by approximately 22%

~ of the evaporative emissions (ADR37 SHED test method) increases by approximately 29%

~ little or no change in total ozone formation potential after weighting exhaust and evaporative emissions (+0.24%)

Note: If evaporative emissions are lower than obtained with ADR37 SHED test method then ozone formation potential is decreased.

♦ Health risk assessment of “toxics” and aldehyde emissions:

~ carcinogenic risk decreased by approximately 24% (Environment Defence Fund risk factors); and,

~ acute and chronic (respiratory, reproductive and neurological) health risks increase by 3% (Environment Defence Fund risk factors).

Note:

1. The increase in acute and chronic health risk is almost entirely due to the estimated increase in acrolein and must therefore be treated with caution.
2. Any increased acute or chronic health risk due to increased acrolein emission is negligible compared to the decreased health risk resulting from decreased CO emission.

- Fuel consumption:
  - ~ increases by 2.6% for the City cycle; and
  - ~ increases by 2.6% for the Highway cycle.

- Hot and Cold drivability:
  - ~ reduced tendency for "knock" under both hot and cold conditions; and,
  - ~ no other significant differences are observed.

- Materials compatibility:
  - ~ there is no discernible effect on any plastic or elastomer materials; and,
  - ~ there is no discernible corrosion in fuel wetted metal parts such as fuel tanks, lines, pressure regulators, etc.

- Engine wear:
  - ~ there is no additional or unusual wear to that normally expected; and
  - ~ there is no additional increase in wear metals or decrease in total base number (TBN) of the lubricating oil.

- Water tolerance:
  - ~ the quality of ethanol produced and stored in its neat form must be of a high standard and the water content maintained below 1.25% w/w;
  - ~ an ethanol compatible water detecting paste must be used to establish the water content of underground storage tanks (standard paste is not suitable) and the water content must be kept to a minimum; and,
  - ~ older vehicles are more prone to suffer from phase separation when first fuelled with ethanol/petrol blend, however subsequent continuous use of ethanol/petrol blend prevents water accumulation within the fuel tank.

1.4 Applications

The use of biomass ethanol in petroleum fuels directly address vehicle exhaust emissions and transport fuel security of supply issues of national and international concern. Most importantly, the renewable ethanol content of these fuels can result in a net reduction in the emission of carbon dioxide.

The 10% v/v anhydrous ethanol/petrol blend as used in NSW, Australia, and internationally requires no modifications to vehicles in service now and in the foreseeable future and requires minimal changes to the fuel distribution infrastructure.

Several alternatives exist to modify the characteristics and ethanol content of the blend. These include:

- Hydrated ethanol/petrol emulsions researched under ERDC Project No: 2512, "Emulsions of Hydrated Ethanol in Hydrocarbon Fuels" directly address issues relating to the use of ethanol/petrol blend in unmodified vehicles. Such an emulsion has a lower vapour pressure, greater water tolerance and, potentially, reduced NOx emission on combustion compared to the 10% v/v anhydrous ethanol/petrol solution currently used.
- Increase the ethanol content to 22-25% v/v (E22) as used in Brazil. This reduces evaporative emissions but requires dedicated engine tune and material compatibility issues need to be addressed.
- Increase the ethanol content to 85% v/v (E85). A dedicated engine/vehicle combination is required. Both Ford and General Motors in the United States produce significant numbers of such vehicles for the US market.

1.5 Commercialisation

Widespread commercial use of ethanol as a petrol supplement dependent upon ethanol availability. Fuel ethanol availability is to a large extent dependent on Federal and State energy, environment and industry policies. To increase investment in fuel ethanol production, governments must encourage fuel ethanol production and use by incentives and/or legislation.

1.6 Benefits

There are a wide and diverse range of benefits to be obtained by industry, the economy, the community and Australia as a whole from an ethanol fuel industry.

These benefits include:

- increased fuel self-sufficiency;
- improved balance of trade/saved foreign exchange; and,
- reduction in vehicle regulated exhaust emissions.

In addition to the above mentioned benefits there are the following important benefits that are uniquely obtained from the use of ethanol fuel produced from biomass:

- Reduced emission of carbon dioxide.
- Expansion of the agricultural economy, value enhancement of existing biomass resources, treatment of land degradation and re-afforestation.
- Nationwide decentralisation and regional industry development.

An ethanol fuel industry is unique insofar as there is no other industry which offers the prospect of achieving a substantial reduction in the emission of carbon dioxide from the transport and industrial sectors whilst simultaneously addressing persistent lack of employment opportunities in rural areas and also providing solutions to land degradation which is arguably the biggest of Australia's environmental problems.

1.7 Recommendations

Ethanol/petroleum fuel blends directly address vehicle exhaust emissions and transport fuel security of supply issues. In addition to reducing currently regulated vehicle emissions, the renewable ethanol content of these fuels can result in a net reduction in the emission of carbon dioxide.

It is recommended that both Federal and State Governments encourage the use of ethanol in blends with hydrocarbon fuels by:

- supporting research and development into new low cost methods of fuel ethanol production; and,
- offering investment incentives to manufacturers and distributors of fuel ethanol.

It is also recommended that further research be conducted to:

- determine the level of evaporative emissions from 10% v/v ethanol/petrol blend under "real world" conditions such as by using the Multiday Diurnal SHED test method in force in the United States since January 1996; and,
- to improve the measurement methods for the determination of the “toxics” and aldehydes in exhaust and evaporative emissions.

2. RECORD OF THE PROJECT

2.1 Work Program

The work program was in several parts, reflecting the project objectives, as follows.

- Emissions - measurement of exhaust and evaporative emissions formed the major part of the project. The parties involved included:
  - ~ NRMA - contracted to prepare vehicles for testing;
  - ~ NSW EPA - contracted to test vehicles in accordance with ADR37 protocols using both neat petrol and 10% v/v ethanol/petrol blend; and
  - ~ CSIRO - contracted by NSW EPA to carry out exhaust gas speciation from selected vehicles and evaluate ozone formation potential.

- Power - evaluated by NSW EPA using an engine dynamometer.

- Fuel consumption - measured as follows:
  - ~ NSW EPA carried out the City and Highway fuel consumption measurements to AS2877-1986 as part of the emissions test protocol;
  - ~ selected vehicle owners were requested to keep fuel consumption records; and,
  - ~ BOGAS customers were requested to complete a fuel consumption survey form.

- Drivability - Hot and Cold Drivability were evaluated according to test protocols supplied by FCAI.
  - ~ Hot Drivability was evaluated in two parts:

    Part 1 - Four almost new vehicles were tested at Bourke, NSW, by NRMA representatives, however the results were not acceptable to the Steering Committee due to low test fuel Reid vapour pressure (RVP).

    Part 2 - Three post 1986 vehicles (two EFI, one carburetted) and one pre 1986 vehicle (LP, carburetted) were tested at Broken Hill, NSW, by a representative of FCAI.

  - ~ Cold drivability was evaluated by NRMA representatives at Londonderry, NSW. Three 1986-on vehicles (two EFI, one carburetted) and one pre 1986 vehicle (LP, carburetted) were tested.

- Materials compatibility

  Materials compatibility evaluation consisted of inspection of the fuel system components fitted to all the vehicles tested for emissions. The parts most likely to be affected i.e. elastomer hoses, fuel filters and strainers, plastic components, fuel tanks etc. were inspected by NRMA Service and Apace personnel. Fuel return hoses were replaced on all vehicles and the removed hoses were subsequently inspected by independent inspectors drawn from IAME, SAE and NRMA.

  A catalytic converter removed from a vehicle known to have operated exclusively on 10% v/v ethanol/petrol blend for 150,000 km was inspected by Prof. N.W. Cant of Macquarie University.

  GUD Pty. Ltd (manufacturers of after market fuel filters) have advised that their fuel filters are ethanol/petrol blend compatible.

  All of the test vehicles were of domestic build however confirmation was received from FCAI that all imported vehicles are compatible with 10% v/v ethanol/petrol blend.

- Engine wear

  A total of four engines were stripped by NRMA at their Villawood workshop and inspected by independent inspectors drawn from IAME, SAE and NRMA.

  Engine oil analysis was carried out by Oilcheck Pty. Ltd and included:

~	Wear metals	~	Fuel dilution
~	Water content	~	Oxidation
~	Viscosity	~	Nitration
~	Pentane insolubles	~	Dispersancy
~	Acid index	~	Total Base Number

- Water tolerance

  Blending, storage, transport and distribution systems were evaluated in conjunction with ethanol/petrol blend marketers.

2.2 Technical Results

The project confirmed the technical and commercial viability of using a 10% v/v ethanol/petrol blend in the existing vehicle fleet.